

An Exploratory Study to Identify an Effective Pedagogical Approach to Teaching Math-Related Content Knowledge in Construction Education

Dr. Namhun Lee, Central Connecticut State University

Dr. Namhun Lee is an Assistant Professor in the Department of Manufacturing & Construction Management at Central Connecticut State University, where he has been teaching Construction Graphics/Quantity Take-Off, Building Construction Systems, Heavy/Highway Construction Estimating, Building Construction Estimating, and Construction Project Management. Dr. Lee's main research areas include: 1) Information Visualization and Decision Support Systems, 2) Building Information Modeling (BIM) and Information and Communication Technology (ICT) for Construction Management, and 3) Interactive Learning Systems Using Games and Simulations. Address: Manufacturing & Construction Management Department, Central Connecticut State University, Copernicus Hall 21206, 1615 Stanley St. P.O. Box 4010, New Britain, CT 06050-4010; telephone: (860) 832-2624; e-mail: leen@ccsu.edu.

Dr. Jacob P. Kovel P.E., Central Connecticut State University

Dr. Jacob Kovel is an associate professor at Central Connecticut State University for 13 years. During that time he has served as the program coordinator for the construction management program and is currently also serving as department chair of the Manufacturing & Construction Management Department. Among his major responsibilities are assessment and accreditation. Prior to that, he spent four years as an assistant professor of architectural engineering at the University of Kansas and was also a lecturer at Georgia Tech. Dr. Kovel spent 28 years in the US Army as an Engineer officer, retiring in 2008 as a lieutenant colonel. He holds a professional engineer license in the Commonwealth of Virginia, originally granted in 1990. Dr. Kovel holds a bachelor's degree in applied sciences and engineering from the United States Military Academy, a master's degree in engineering management from the University of Missouri-Rolla and a Ph.D. in civil engineering from Georgia Tech.

Dr. Lee W. Lee, Central Connecticut State University

Chair and Professor at Central Connecticut State University Department of Management and Organization
Senior Fulbright Scholar

An Exploratory Study to Identify an Effective Pedagogical Approach to Teaching Math-Related Content Knowledge in Construction Education

Introduction

Brown¹ and Mohr² mentioned that reading, writing, and math skills are essential in any kind of workplace. In the construction industry, the capacity for quantitative thought and expression is essential in the workplace since everyone working in the construction management (CM) domain use construction-related mathematics in many aspects of their work every day. Construction-related math includes simple measurements, unit conversions, calculations with decimals and fractions, scale factor, right triangle trigonometry, and calculations for lengths, areas, and volumes. Even though students have been taught these math concepts since 3rd grade, surprisingly a considerable number of CM students in higher education systems do not perform well on them.

For success on the construction job, the most important factor is an aptitude and interest in construction. Other important factors include the ability to work as part of a team and a keen understanding of mathematics. The National Association of State Directors of Career Technical Education Consortium³ clearly defines the mathematical knowledge and skills used in the construction sector. This definition includes algebra, geometry, trigonometry, calculus, and statistics.

Davis⁴ investigated math skills of freshmen-level students in the CM program at Boise State University with a diagnostic math quiz. Her study concludes that high percentages of the students are not prepared for college-level coursework and need to take a remedial math course. We do not believe that this problem is only limited to the freshmen-level students in the CM program at Boise State University. From previous literature, several researchers^{5,6,7} also claimed that over 70% of entering college students must take remedial math coursework.

Many CM programs require students to take math courses such as college algebra, applied trigonometry, and applied calculus as general education courses or pre-requisites. However, students who passed the math requirements still have difficulty in the application of the math skills to construction-related context. This is because students have been exposed to math problems without true understanding of math concepts⁸. Within CM curricula, there are several math-related courses such as structural analysis, surveying, construction and civil materials, soils, foundations, equipment management, cost estimating, and AutoCAD. Without confidence in math, students may fail these courses and drop out of college⁹. Therefore, fundamental math skills should be developed before students reach upper level courses. Students must be able to confidently solve construction-related math problems by the time they graduate.

Research Purpose and Method

The main purpose of this study is to explore different pedagogies and identify an effective one to teach math-related content knowledge in construction education. This study investigated three

pedagogical approaches to teach math-related CM courses: the traditional lecture model, the problem-based learning model, and the flipped classroom model. For this study, students' performance data on pre- and post-tests were collected from three different sections of an upper level CM course (CMGT 4000: Construction Estimating) at East Carolina University from 2010 to 2012. One section of the course used the traditional lecture model, another section used the problem-based learning model, and the other section used the flipped classroom model to teach quantity surveying techniques for both "sitework" and "concrete" estimating to investigate which approach is most effective.

Background Study

Mathematics for Construction Estimating

To identify the necessary mathematical concepts for the quantity takeoff, two faculty members who taught estimating over three years at the college level and one professional estimator who worked for construction trades over ten years talked together. As the result of the discussion, the following mathematical concepts were identified:

- Fractions, decimals, and percents
- Ratio and proportion
- Angles and triangles
- Lengths and perimeters
- Areas and volumes
- Unit conversions

These concepts are fundamental but essential to building construction works. The professional estimator said, "Most junior estimators learned the concepts at some point, but struggle with them when performing the quantity takeoff." Therefore, the basic mathematical concepts should be mastered by the time students graduate to confidently solve any math problems in contexts of construction work. Inches and fractions of an inch need to be converted into decimal feet comfortably to add and check dimensions. Lengths, areas, and volumes should be easily calculated to determine the quantities of materials required to complete the building project. In many cases, the quantities from one set of units may be required to be converted to another set of units (e.g. cubic feet to cubic yards, cubic yards to square yards, loose cubic yards to compacted cubic yards, cubic feet to bank feet in trench excavation, etc.).

Problem-Based Learning Model

Constructivism claims that learners construct their own knowledge through interacting with the external world and interpreting the experience¹⁰. This learning process will be facilitated when learners are actively involved in a targeted learning context through collaborations and social interactions. From the constructivist's view, the instructor should provide students with a learning environment embedded in a real-world context where students can interact with peers to accomplish a task. In this learning environment, students can realize multiple perspectives to solve a problem and critically think of what they learned. In this case, the instruction should articulately describe the task, not define the structure of learning required to accomplish a task.

Behaviorists postulate that learning can be caused by external stimuli in the environment and is indicated by an observable behavior¹¹. Real-world problems serve as the stimulus for learning. Students encounter real-world and open-ended situations in a small group and the instructor guides and facilitates their learning process by asking questions and monitoring the problem solving process. Students acquire requisite knowledge, critical thinking and problem-solving skills by analyzing and solving problems. Hence, when designing problem-based learning, the emphasis must be placed on analyzing behavioral objectives and assessing learner performance with criterion-referenced tests. In the problem-based learning approach, learning should be reinforced through teaching strategies such as frequent cues, stimulus-response chaining, feedback, and repertoires¹².

Learning results from learners' actions and instructions play a vital role as they enable and foster constructive activities¹³. Thus, the instructor should focus on helping students be able to acquire the necessary skills in their learning. Problem-based learning should focus on the process of learning, rather than the outcome of a task. According to Hmelo and Evensen¹⁴, the major goals of the problem-based learning approach are problem-solving, self-directed learning, and team-based or collaborative learning. The characteristics of a PBL module can be described as follows¹⁵:

- Learning is student-centered.
- Learning occurs in small student groups.
- The instructor is a facilitator or a guide.
- Problems form the organizing focus and stimulus for learning.
- Problems are a vehicle for the development of problem-solving skills.
- New information is acquired through self-directed learning.

Flipped Classroom Model

The use of personal computers and the world-wide-web has been the mainstream since the 1990s, which made it possible to shift from a traditional lecture-based format to the flipped classroom model. The flipped, or inverted, classroom is an instructional model in which the lecture and application modules of a course are reversed. Baker¹⁶ advocated for the application of online instructional tools to free classroom time for collaborative learning. Baker's sentiment is echoed in Mazur's current application¹⁷ (called Learning Catalytics) of the flipped classroom model to encourage student participation and collaboration through a cloud-based interactive education system.

In the flipped classroom model, the information element, or lecture, is reviewed outside of the designated classtime by means of web-based informational videos, power point slides, podcasts, and online readings. Students should be encouraged to actively review outside learning components. Students can take notes by pausing and re-watching sections that are unclear or information dense, record any questions they may have, and summarize their learning. In this way, students can gauge their own initial understanding of the material¹⁸. Students' comprehension and retention of the online material is assessed by quizzes, administered online or in class, web-based interactive discussion boards, or as an open ended, student-led discussion on

the lecture topic in initial minutes of class time. Any misunderstandings or unclear material can be addressed through additional examples or explanation¹⁹. This classtime is usually given to application modules where students apply the knowledge to hands-on activities including group work, case studies, computations, interactive assessments, or student facilitated workshops under the supervision of the instructor. A 2012 Educause article likened the flipped classroom to a workshop or “studio where students create, collaborate, and put into practice what they learned from the lectures they viewed outside class”²⁰. The main objective of the flipped classroom should be to enhance student understanding through differentiated instruction and hands-on experience²¹.

In this model, the instructor acts as an overall facilitator, monitoring student engagement and understanding. The instructor moves around the classroom to provide individual instruction and instantaneous feedback. The instructor can assess student engagement and understanding through a learning management system such as Blackboard or Moodle by creating a quiz or an open-ended question. Then, students access to the system via smart phones, iPads, or computers outside of the designated classtime in order to complete the online quiz or respond to the question. Using the learning management system, the instructor can analyze the student responses and tailor interactive classroom time to students’ needs.

Research Design

To examine the effect of the three pedagogical approaches to teaching math-related content knowledge in construction education, fifty two undergraduate students who enrolled in CMGT 4000: Construction Estimating classes at East Carolina University from 2010 to 2012 were assigned at random to three groups: Group #1 was taught using the traditional lecture model; Group #2 was taught using the problem-based learning model to deliver the course content; and Group #3 was taught using the flipped classroom model. Participants included fifty males and two females, primarily juniors (N=29) and seniors (N=23). All of the participants were majoring in construction management.

In this study, the groups being compared were not assumed to be equivalent at the beginning of the study. Any differences observed at the end of the study might not have been caused by the intervention, but were due to pre-existing differences. Thus, this study included the nonequivalent control group design, where both control and experimental groups are pretested and posttested. All of the participants in the each group were required to take both pretest and posttest. The scores on each test ranged from 0 to 15.

Control Group	P ₁	--	P ₂
Experimental Group #1	P ₁	I ₁	P ₂
Experimental Group #2	P ₁	I ₂	P ₂

P₁ represents a pretest measure; P₂ represents a posttest measure; I₁ represents an intervention #1 (the problem-based learning model); and I₂ represents an intervention #2 (the flipped classroom model). Experimental group #1 and experimental group #2 members received the intervention of the problem-based learning model and the flipped classroom model, respectively. On the other

hand, control group members do not received any treatment, which means they were taught from the traditional lecture model.

This research design involved measuring the dependent variable (i.e., students’ conceptual understanding on math-related content knowledge and students’ ability in quantity takeoff) both before and after the intervention. The frequency distributions of the “change” score (also called a “gain” scores) of each group, which is the difference between the posttest score and the pretest score, were compared. In addition, the analysis of variance (ANOVA) test was used to compare the means of the change scores of three independent samples and to test whether the differences between the change scores are statistically significant. Using ANOVA, the error level can be kept at the 5% level.

As described above, three instructional methods were tested: the traditional lecture model, the problem-based learning model, and the flipped classroom model. In this study, the independent variable is the instructional methods since they define the groups that are compared. The dependent variable is students’ change scores whose means are being compared. Figure 1 shows the research frame and topics associated with this study.

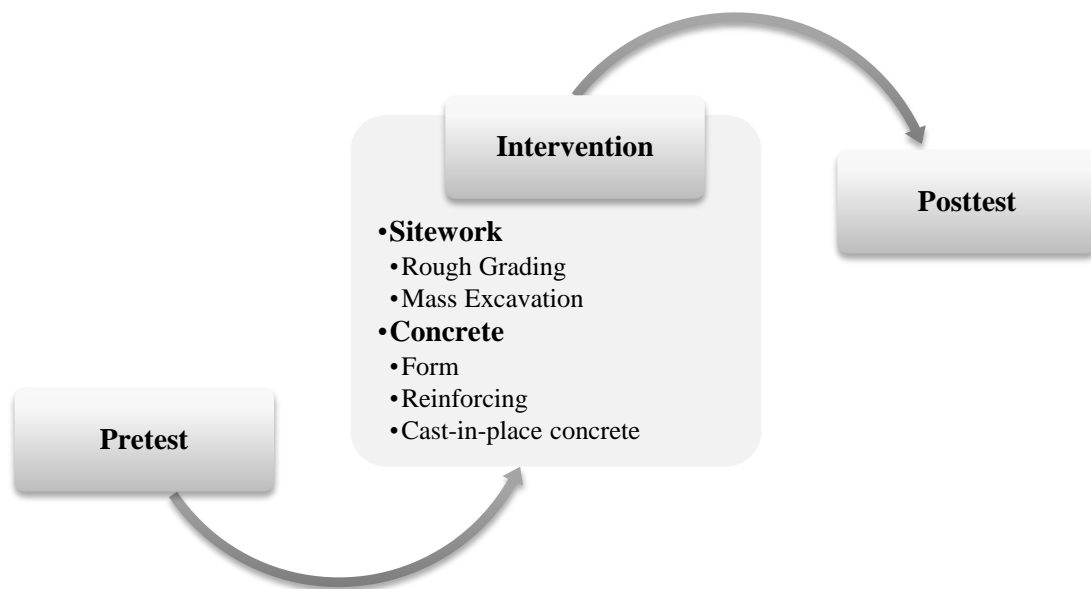


Figure 1. Research Frame and Topics

At the end of this study, the change scores of the students who were taught the course topics of “Sitework” and “Concrete” using the three instructional approaches were measured and compared to each other using a one-way ANOVA. The ratio of the variance between groups to the variance within groups (also know as “F ratio”) was used to assess whether there are significant differences in the mean scores of the three groups of students.

With the three groups, the null hypothesis (H_0) was stated as follows:

$H_0: \mu_1 = \mu_2 = \mu_3$, which means the means of the change scores of the three groups are statistically equal across the three types of instructional methods.

This null hypothesis can be rejected if there is a statistically significant difference between at least two means. Since there were three groups, the alternative hypothesis (H_a) was:

$H_a: \mu_1 \neq \mu_2$ and/or $\mu_2 \neq \mu_3$ and/or $\mu_3 \neq \mu_1$, which means there is a significant difference between at least two of the three means.

Data Analysis and Results

To determine the pre-existing differences, pretest scores in each group were first measured. Then, posttest scores were measured to identify the effect of the independent variable (i.e., the instructional methods). Table 1 shows descriptive statistics for both pretest and posttest scores of the three groups. From this data, it appears that the use of the problem-based learning model produced a greater change in test scores.

Table 1. Descriptive Statistics for the Pretest and Posttest Scores

	Group #1		Group #2		Group #3	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Range	1-7	4-14	0-8	6-15	1-8	4-15
Mean	3.71	8.21	3.8	10.8	3.89	9.17
S.D.	2.05	3.09	2.28	2.63	2.00	3.31

Figure 2 illustrates frequency distributions in percentages, compared to the change scores, which represent the effects of the instructional methods. 40% of students in group #2 have a change score of 8 or more. Compared to this data, only 7% and 28% of students have the same in group #1 and group #3, respectively.

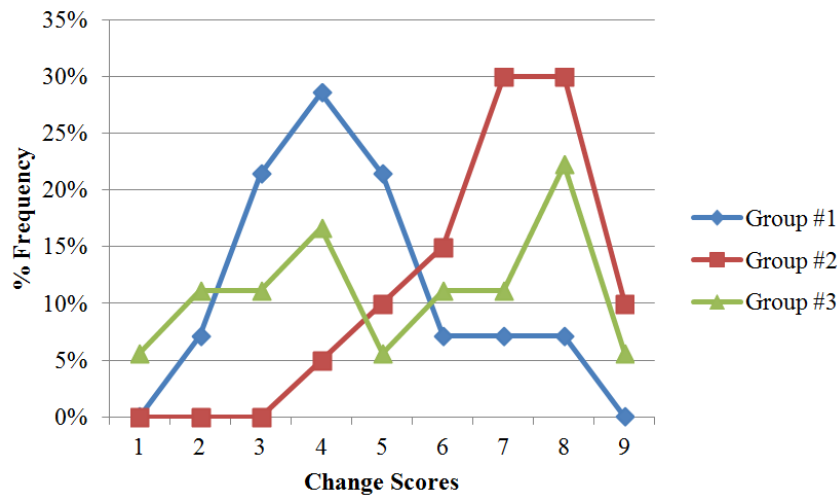


Figure 2. Frequency Distributions of the Change Scores

Table 2 lists the descriptive statistics for the change scores in each group. As shown in Table 2, the difference between the pretest means and posttest means of each group is 4.5 in group #1, 7

in group #2, and 5.28 in group #3. Students in group #2 where the instructional method was the problem-based learning model obtained the highest change score.

Table 2. Descriptive Statistics for the Change Scores

	<i>Group #1</i>	<i>Group #2</i>	<i>Group #3</i>
Range	2-8	4-9	1-9
Mean	4.5	7	5.28
S.D.	1.65	1.34	2.49

The ANOVA was used to test whether these differences are statistically significant or it happened purely by chance. The numerical results including the sources of variability (SS), the degrees of freedom (df), the mean squares (MS), the F ratio, and the p value are displayed in Table 3.

Table 3. ANOVA Summary

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>
Between Groups	57.12	2	28.56	7.99	<0.01
Within Groups	175.11	49	3.57		
Total	232.23	51			

As shown in Table 3, the obtained F ratio of 7.99 exceeds the critical F value (5.07) at $p=.01$ probability level and the result is significant at $p<.01$, which means there is a statistically significant difference between at least one pair of means. Therefore, the null hypothesis (H_0) was rejected in favor of the alternative hypothesis (H_a). As is indicated in Table 2 & 3, the instructional method does make a difference in the students' test scores.

Since the obtained F ratio was significant at the $p<.01$ level, a post hoc comparison was conducted to find out which means are significantly different from each other. The honestly significant difference (HSD) value tells us what the difference between a pair of means should be in order to view the means as significantly different from each other²². Any difference that exceeds the HSD value is considered statistically significant. In this study, the degree of freedom within (df_w) and the number of groups (K) are 49 and 3, respectively. The corresponding Q value for the .05 level of significant is 3.42, and for the .01 level it is 4.32. The HSD value at the $p=.05$ and $p=.01$ level of significant are 1.55 and 1.96, respectively.

Table 4. Means for Three Groups: Post Hoc Comparison

	<i>Group #1</i>	<i>Group #3</i>	<i>Group #2</i>
	$X_1=4.5$	$X_3=5.28$	$X_2=7$
<i>Group #1</i>	--	0.78	2.5**
<i>Group #3</i>		--	1.72*
<i>Group #2</i>			--

Note: X is the means of the change scores in each group. * $p<.05$, ** $p<.01$

Table 4 shows the difference between the means of the change scores in group 2 (the problem-based learning model) and group #1 (the traditional lecture model) is significant at $p<0.01$. Also, the difference between the means of the change scores in group 2 (the problem-based learning

model) and group #3 (the flipped classroom model) is significant at $p < 0.05$. No other means are significantly different from each other. Therefore, the likelihood “that the decision to reject the null hypothesis is wrong” is low. This study tested that the choice of instructional method in teaching estimating affects students’ test scores. Thus, the problem-based learning models would be the most effective pedagogical approach to teaching math-related content knowledge in construction education, compared to both the flipped classroom model and the traditional lecture model.

Conclusions

Along with teamwork and communication skills, math skills are essential in many types of construction projects. Construction professionals deal with numerous math-related problems from site layout to roof assembly in a construction project. Mathematics play a key role in every phase of the construction process. To help students build necessary math skills in contexts of construction management, this study tested three instructional approaches: the traditional lecture model, the problem-based learning model, and the flipped classroom model paper. Based on the results of this exploratory study, the problem-based learning is an effective pedagogical approach to teaching math-related content knowledge in construction education.

Typically in the problem-based learning approach, the instructor’s main role should be as a guide and facilitator to share information with students, support creativity, promote interaction among students to solve problems, and respond to students’ cognitive needs and development. In this instructional method, students will be able to develop problem-solving, critical thinking, metacognitive, and social skills to better prepare themselves for professional careers. Therefore, practical pedagogical strategies for improving students’ math skills must be developed to provide a rich and active learning environment in which students will be able to not only build confidence in math but also learn necessary math-related content knowledge in construction.

Bibliography

1. Brown, D. (2005). “Poor reading, math skills a drag on productivity, performance.” *Canadian HR Reporter*, 18(4), 1.
2. Mohr, C. (2008). “Aligning Classroom Instruction with Workplace Skills: Equipping CTE Students with the Math Skills Necessary for Entry-Level Carpentry.” *Techniques: Connecting Education and Careers*, 83(8), 34-38.
3. National Association of State Directors of Career Technical Education Consortium: the construction pathway of the architectural and construction career cluster. <http://www.careertech.org/career-clusters/resources/plans/architecture.html>
4. Davis, K. A. (2011). “A survey of construction-related math skills in an introductory-level construction management course.” *118th ASEE Annual Conference and Exposition, June 26-29, 2011, Vancouver, BC, Canada*.
5. Hoyt, J. E. and Sorensen, C. T. (2001). “High School Preparation, Placement Testing, and College Remediation.” *Journal of Developmental Education*, 25(2), 26-34.

6. Hudspeth, M. C. (1978). "Teach Remedial Mathematics at Our University?" *The Journal of General Education*, 30(2), 117-128.
7. Trenholm, S. (2006). "A Study on the Efficacy of Computer-Mediated Developmental Math Instruction for Traditional Community College Students." *Research & Teaching in Developmental Education*, 22(2), 51-62.
8. Worthington, M. and S.D. Jones. (2007). "Adult Perceptions of Their Abilities in Math." *Exchange*(174), 52-54.
9. Pang, T. (2010). "Improve Math Education, Improve Student Retention." *Chronicle of Higher Education*, 56 (19), A30.
10. Jonassen, D. H. (1991). Evaluating Constructivistic Learning, *Educational Technology*, 31(9): 29-33.
11. Skinner, B. F. (1974). *About Behaviorism*, New York: Knopf.
12. Lee, N. (2013). "A Conceptual Framework for Technology-Enhanced Problem-Based Learning in Construction Engineering and Management Education." 120th ASEE Annual Conference and Exposition, June 23-26, 2013, Atlanta, GA, USA.
13. Lee, N. (2011). Instructional Design for a Web-Enhanced Course in Construction Engineering and Management Education, ASC 47th Annual International Conference.
14. Hmelo, C. E. & Evensen, D. H. (2000). Introduction to Problem-Based Learning: Gaining Insights on Learning Interactions through Multiple Methods of Inquiry. In D. H. Evensen and C. E. Hmelo (Eds), *Problem-Based Learning: A Research Perspective on Learning Interactions*. Mahwah, N.J.: Erlbaum, 1-16.
15. Gallagher, S., Stephien, W., Sher, B., & Workman, D. (1995). Implementing Problem-Based Learning in Science Classrooms, *School Science and Mathematics*, 95: 136-146.
16. Baker, J. W. (2000). The "classroom flip". Using web course management tools to become the guide on the side. 11th international conference on college teaching and learning, Jacksonville, FL.
17. New, J. (2013). Pearson Acquires Learning Catalytics, a Cloud-Based Assessment System. *The Chronicle of Higher Education*, Retrieved on December 29, 2013 from <http://chronicle.com/blogs/wiredcampus/pearson-acquires-learning-catalytics-a-cloud-based-assessment-system/43543>
18. Bergmann, J. & Sams, A. (2012). *Flip Your Classroom: Reach Every Student in Every Class Every Day*. ISTE and ASCD, Alexandria, VA.
19. Demski, J. (2013). Six expert tips for flipping the classroom. *Campus Technology*. 1-5. <http://campustechnology.com/articles/2013/01/23/6-expert-tips-for-flipping-the-classroom.aspx>
20. Educause. (2012). Seven things you should know about... flipped classrooms. <http://net.educause.edu/ir/library/pdf/eli7081.pdf>
21. Rogers, T., & Tingerthall, J. (2013). Blended learning and 'flipping' the construction management classroom for improved teaching and learning. 49th Annual International Conference Proceedings.
22. Marascuilo, L. A. & Levin, J. R. (1970). "Appropriate Post Hoc Comparisons for Interaction and Nested Hypotheses in Analysis of Variance Designs: The Elimination of Type IV Errors." *American Educational Research Journal*, 7(3): 397-421.